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# THE MANURING OF COTTON.

(Condensed from an article by H. C. White, Ph. D., in Bulletin No. 33  
of the Office of Experiment Stations.)

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# THE MANURING OF COTTON.

## THE DRAFT OF THE COTTON PLANT UPON THE FERTILITY OF THE SOIL.

One of the most important lines of investigation which the agricultural experiment stations have undertaken in relation to the cotton plant is the study of its chemical composition. These studies have confirmed the view generally held by planters that the cotton plant makes a light draft upon the fertility of the soil. They show that a crop yielding 100 pounds of lint per acre removes from the soil the following amounts of fertilizing ingredients:

*Fertilizing constituents in a crop of cotton yielding 100 pounds of lint per acre.*

[Pounds per acre.]

	Nitrogen.	Phosphoric acid.	Potash.	Lime.	Magnesia.
Roots (83 pounds).....	0.76	0.43	1.06	0.53	0.34
Stems (219 pounds).....	3.20	1.29	3.09	2.12	.92
Leaves (192 pounds).....	0.10	2.28	3.46	8.52	1.67
Bolls (135 pounds).....	3.43	1.30	2.44	.09	.54
Seed (218 pounds).....	0.82	2.77	2.55	.55	1.20
Lint (100 pounds).....	.34	.10	.46	.19	.08
Total crop (847 pounds).....	20.71	8.17	13.00	12.60	4.75

McBrydo has shown "that even when the seed is taken away along with the lint, cotton still removes smaller amounts of fertilizing materials from the soil than either oats or corn." It is an important fact that the lint and the oil, whose fertilizing constituents alone are necessarily permanently lost to the farm, contain comparatively insignificant amounts of these constituents. If, therefore, the roots, stems, leaves, etc., are turned under, and the hulls and meal used on the farm upon which the cotton was grown, cotton is the least exhaustive of the staple crops to the soil.

These figures are given as merely indicating the fertilizer requirements of the cotton plant and not as representing the exact amounts of fertilizing materials which should be applied to it under all conditions. As shown later, the amounts of the different fertilizing constituents recommended for use are much larger than indicated by this table. Soils vary widely in the amounts of potash, phosphoric acid, and nitrogen which they contain, and these variations, together with numerous other conditions the influence of which can only be determined by experiment, must be taken into consideration in deciding upon the exact fertilizer mixture needed.

## EXPERIMENTS ON THE MANURING OF COTTON.

As stated above, the experiment stations have undertaken to solve some of the questions bearing directly upon the manuring of cotton.

Omitting mention of such experiments as were manifestly unreliable by reason of accident, omissions, lack of care and attention, or from other causes, a succinct review of the results obtained in the several lines of experimentation is here presented.

YIELD AND PROFIT FROM THE USE OF FERTILIZERS ON COTTON AS COMPARED WITH  
YIELD AND PROFIT FROM UNFERTILIZED SOIL.

The results of experiments instituted on this line vary greatly with the nature of the soil, the seasons, the culture, and the kinds and amounts of manures employed. With the exception of those upon one class of soils, however, they all agree in demonstrating that large profit attends the judicious manuring of cotton. The exception is in the case of the "black prairie" or "canebrake" soils of the alluvial formations of the Gulf States. Experiments upon such soils at the Alabama stations indicate that no compensating returns may be expected from the use of manures "except crushed cotton seed and cotton-seed meal, and even with these the returns are small." Drainage and good mechanical tillage seem to be the chief need of these soils. Upon other soils of Alabama, however, "the percentage of profit from a judicious use of fertilizers, followed by intelligent cultivation, is most satisfactory." Upon a poor sandy soil, with no retentive clay within 3 feet of the surface, "even with unusual expense for fertilizers, the increase resulting from the use of commercial manures paid 85 per cent profit on cost."

Experiments made under direction of the Arkansas Station indicate that "fertilizers are generally remunerative," the percentage of profit ranging from 20 to 180. Five hundred pounds per acre of rotted cotton seed gave a net profit of \$3.93. Five hundred pounds each of cotton seed (at \$6.50 per ton) and cotton-seed meal (at \$20 per ton) gave equal financial profit.

At the Georgia Station the use of commercial fertilizers was almost always profitable, the percentage of profit ranging from 5 to 250.

The stations of Louisiana, Mississippi, North Carolina, and South Carolina obtain similar results from experiments, and indicate that "the application of fertilizing material to cotton seems, with few exceptions, to be profitable."

To the teaching of these specific experiments may be added the general experience of the great bulk of the cotton planters, and it may be accepted as proven that cotton responds favorably to artificial manuring, and that upon most of the soils of the cotton States all kinds of manures, including concentrated commercial fertilizers at the prices at which they are commonly held, are profitable when judiciously used.

COMPARATIVE VALUES OF COMMERCIAL FERTILIZERS AND HOME MANURES.

Results of experiments on this point also vary considerably with the soil and season.

In Alabama, green manuring appears to have been most profitable upon both prairie and sandy soils. Peas and melilotus both gave good results; pea vines appeared to be the best fertilizer for cotton; peas were more economical for green manuring for one season,

melilotus for two; stable manure generally gave good results, lasting in effects; upon canebrake soils, both drained and undrained, crushed cotton seed and stable manure each gave small returns, commercial fertilizers none. Upon a field with sandy soil which had not been cultivated for many years stable manure, contrasted with chemical manures of various kinds and in various proportions, produced the largest increase and the largest profit per acre, but it was noted that the amount applied was at the rate of nearly 2 tons per acre, or one-half ton more than the amount annually saved from each mule kept. "There is no question about the efficacy of good stable manure properly used, but the available supply is too small."

In Arkansas, cotton seed and cotton-seed meal gave best results when tested against acid phosphate and kainit separately. On worn sandy bottom lands almost continuously planted in cotton for thirty years cotton-seed meal and stable manure each gave better results than chemical manures, and better results when used alone than when mixed with acid phosphate and kainit. "There is no better fertilizer for cotton than stable and barnyard manure." Other experiments indicated, however, that stable manure (from feeding cotton seed and pea-vine hay) extended the growing season of the plant, delayed maturity of the crop, and hence decreased the possible yield and profit.

In Georgia, cotton seed and stable manure alone were found unprofitable as compared with the same composted with acid phosphate, and gave less profit, when used in amounts of equal cost, than chemical manures.

In Louisiana, cotton seed and stable manure alone were of doubtful profit as compared with chemical manures. "Manure from the farm should be reenforced with cotton-seed meal and composted with acid phosphate. \* \* \* The compost is the best manure in the world for cotton." The formula recommended for the compost is—

Green cotton seed.....	bushels..	100
Stable manure.....	do.....	100
Acid phosphate.....	pounds..	2,000

Almost as effective as the compost was a homemade chemical manure, constructed as follows:

	Pounds.
Acid phosphate .....	1,100
Cotton-seed meal.....	700
Kainit .....	200

In Mississippi, commercial fertilizers were more profitable than stable manure or cotton seed alone, but paid best in connection with an abundance of organic matter. Composts variously proportioned gave best results.

In North Carolina, barnyard manure was found to be especially effective, partly on account of its after effects, and somewhat the best of all fertilizers. Its first cost (\$1 per load), however, detracted from the profit, and a combination with acid phosphate was much more profitable.

Home composts gave generally good results, and next to these a home mixture of—

	Pounds per acre.
Acid phosphate .....	200
Cotton-seed meal.....	100
Kainit .....	50

**KIND OF FERTILIZER (CHEMICAL MANURE) REQUIRED BY OR BEST SUITED TO COTTON.**

Assuming phosphoric acid, potash, and nitrogen in suitable compounds to be the three chemical substances proper and possible to be used in the fertilization of cotton, the experiments have been mainly conducted with a view to determine the relative importance of these, the best form of each (i. e., of the compounds available in commerce), and the proportions of each in a mixed fertilizer most suitable to the requirements of the cotton crop, regard being had to the character of the soil to which they were applied and account being taken of the profit afforded.

In Alabama, in 1888, experiments were made upon a sandy drift soil to determine the proper ratio of nitrogen to phosphoric acid in fertilizers for cotton. The amount of phosphoric acid was constant—200 pounds of English superphosphate (12 per cent soluble) per acre—and the amount of nitrogen (in dried blood and cotton-seed meal) varied so as to furnish 1 part nitrogen to 1, 2, 4, 6, and 8 parts phosphoric acid. The smallest quantity of nitrogen employed gave as good results as larger quantities. No difference was observed in the two sources of nitrogen. In 1889 cooperative experiments under direction of the Collège Station were made on 9 farms furnishing typical soils of the State. The fertilizers used and the amounts per acre were: For nitrogen, sulphate of ammonia, 80 pounds; nitrate of soda, 100 pounds; cotton-seed meal, 200 pounds; for phosphoric acid, dissolved boneblack, 200 pounds; for potash, kainit, 100 pounds. Green cotton seed (960 pounds per acre) and stable manure (3,000 pounds per acre) alone and in combination with acid phosphate were also used. The fertilizers were applied singly and in various combinations to fifteenth-acre plats without duplication. Some of the experiments proved to be of little value, owing to mistakes and omissions; others indicated with some clearness that phosphoric acid was the ingredient chiefly needed in the soils tested—sandy and brown loam, with clay sub-soil. An experiment was also made with cotton on newly cleared land, in which acid phosphate was applied on two plats, acid phosphate and cotton-seed meal on two, and no manure on one. The results indicated that the natural soil did not furnish sufficient nitrogen and was very deficient in phosphoric acid for the requirements of the crop. In 1890 an experiment was made on fifteen plats in a field which had not been cultivated for many years. The fertilizers used were sulphate of ammonia, dissolved boneblack, and kainit, singly, two and two, and all three together. Floats, alone and in combination, separately, with sulphate of ammonia and green cotton seed, was also used, as also stable manure and green cotton seed singly. Contrast was made with plats receiving no manure. The results indicated that this soil needed nitrogen and

potash, but was most deficient in phosphoric acid for the production of the crop. This experiment and another on a sandy drift land long in cultivation indicated that floats, in connection with cotton seed, was more profitable than acid phosphate. In 1891 cooperative experiments were made on 36 farms in various parts of the State with different fertilizers in different amounts and combinations. The experiments were not perfectly accurate, but indicated certain conclusions. Potash did not seem to pay; phosphates applied alone did not have much effect; nitrogenous fertilizers in all forms gave an increased yield. In 1893 certain experiments indicated that nitrogenous fertilizers (cotton-seed meal and nitrate of soda) alone on cotton pay on sandy lands, providing there are good rains following their application.

The general indications afforded by the great number and variety of cooperative experiments made since 1888 under the auspices of the Alabama Station, upon a variety of soils of the State, the majority of which were sandy, are that a complete fertilizer is needed for cotton. Phosphoric acid is often the controlling element, and a sufficiency of nitrogen is frequently lacking in the soil. Potash alone does not pay. Phosphates applied alone have some effect, but much less than when combined with nitrogen. Nitrogen, particularly in organic forms, is profitable, especially in connection with phosphates. The unfertilized soil of the station needs nitrogen, potash, and phosphoric acid. It is especially deficient in the latter. "In new ground the decomposition of the vegetable matter in the soil did not furnish all of the nitrogen needed by the cotton; the increase from phosphates alone was satisfactory, but the increase caused by the addition of nitrogen did not justify its use." As to floats, the experience of several years indicated that a part of the phosphoric acid becomes available to the plant the first season, but the solubility is much facilitated by combining the floats with cotton seed or cotton-seed meal.

In Arkansas, in 1889, experiments were made on sandy bottom land which had been almost continuously planted in cotton, without manuring, for thirty years. Acid phosphate, cotton-seed meal, and kainit were used singly and in combination; also stable manure and composts in different amounts. Nitrogenous manures alone were profitable. Neither acid phosphate nor kainit alone paid. All of the different plats on which cotton-seed meal was used, either singly or in combination, gave some profit, and "this was due not to the acid phosphate or kainit, but to the cotton-seed meal." These results were confirmed by similar experiments made in 1891. Cooperative experiments made in 1888 at five points in the State, and repeated in subsequent years, indicated that a complete chemical fertilizer is needed for cotton. A combination is provisionally recommended of—

	Pounds per acre.
Acid phosphate .....	200
Cotton-seed meal .....	200
Muriate of potash.....	50



In Georgia a series of excellently arranged and very carefully conducted experiments have been in progress upon the station farm since 1890. The soil of the station is somewhat irregular in character, but is, for the most part, a gray sandy loam underlaid by yellow clay and, previous to the institution of the experiments, had been in continuous cultivation for a number of years. Fertilizing materials in great variety and in many different combinations were used. The results of the experiments have not been strictly accordant, but the following general conclusions seem to be provisionally warranted. Cotton requires a complete manure, i. e., one containing soluble phosphoric acid, potash, and nitrogen. Neither phosphoric acid nor potash give as good results alone as when combined with each other. Phosphoric acid alone largely surpasses no manure. Potash alone is doubtful; sometimes it affects the yield injuriously. Nitrogen alone has little or no effect, but has very decided effects when mixed with phosphoric acid and potash. In some cases nitrogen seems to be the controlling element in a fertilizer, but, on the whole, phosphoric acid is most effective in increasing the yield. Cotton-seed meal (and cotton seed) and nitrate of soda seem to be the best forms of nitrogen for cotton and are about equal in value, proportionately to the content of nitrogen. There is little or no difference in the value of kainit and muriate of potash. The phosphoric acid in floats and Florida soft phosphate is not in a sufficiently soluble and available condition to answer the needs of the cotton crop. The best proportions of the three elements in a complete fertilizer for cotton are, approximately, nitrogen, 1 part; potash, 1 part; phosphoric acid,  $3\frac{1}{2}$  parts. Of such a complete fertilizer the quantity to be used per acre should be an amount furnishing nitrogen, 20 pounds; potash, 20 pounds; phosphoric acid, 70 pounds.

In Louisiana admirably conceived and carefully conducted series of field experiments in the fertilization of cotton have been made both at the State Station, at Baton Rouge, and at the North Louisiana Station, at Calhoun, beginning in 1886 and still in progress. Plats of uniform size were manured with nitrogenous, phosphatic, and potash fertilizers of different kinds and in different proportions, separately and in great variety of combination. The questions tested were:

(1) Do these soils (the worn "sandy lands" and "red lands" of Louisiana) need nitrogen to grow cotton profitably? If so, in what form can it be best presented, and in what quantities per acre?

(2) Do these soils need phosphoric acid? If so, which is the best form, and in what quantities per acre?

(3) Do these soils need potash? If so, which is the best form, and in what quantities per acre?

The results of the experiments were, in some instances, inconclusive, and in some apparently contradictory, as the seasons and the conditions varied. On the whole, however, the following conclusions seem justified as the result of the entire series of experiments:

(1) These soils need nitrogen, and nitrogenous manures may profitably be used in the fertilization of cotton.

(1a) All forms of nitrogenous matters (vegetable, animal, and mineral) are satisfactory and profitable, but, on the whole, they stand in the following order of excellence: (a) vegetable (cotton seed and cotton-seed meal); (b) animal (dried blood, fish scrap etc.); and (c) mineral (sulphate of ammonia and nitrate of soda).

(1b) One ration (24 pounds) of nitrogen per acre is more profitable than larger quantities.

(2) These soils need phosphoric acid. Phosphatic manures may be profitably used in the fertilization of cotton. They are not so necessary (upon these soils), however, as nitrogen.

(2a) The soluble forms of phosphoric acid (in dissolved boneblack and acid phosphate) are emphatically better than the insoluble forms (in floats and similar materials).

(2b) One ration (24 pounds per acre) of phosphoric acid is more profitable than larger quantities.

(3) Potash in no form, either alone or combined with other manures, is needed for these soils. Potash manures are not profitable in the fertilization of cotton.

"It is very certain that phosphoric acid is needed to grow cotton successfully, but in small quantities and combined always with nitrogenous manures."

In Mississippi experiments in the fertilization of cotton were made at the College Station and at Holly Springs in 1888-1893. The results indicate that on upland soils the fertilizer should be rich in organic matter and nitrogen and contain more potash than phosphoric acid. On sandy valley lands the phosphoric acid should predominate. Lime soils require large quantities of potash. On soils poor in lime potash was not needed or did not pay. On black prairie lands the value of concentrated fertilizers was not definitely indicated. The results in different years were conflicting. Cotton-hull ashes were found to be an excellent form of potash.

In North Carolina experiments "on representative soils of the chief geological areas in the State" were conducted in 1890-1894. Stable manure gave best general results in yield, but was not always most profitable on account of initial cost. Next to stable manure, a "complete fertilizer" gave best results, and the proportions per acre recommended are:

	Pounds.
Acid phosphate.....	200
Cotton-seed meal .....	100
Kainit.....	50

Acid phosphate alone was, for the most part, profitable. Cotton-seed meal alone was profitable in the majority of cases. Kainit alone was unprofitable except in the case of the poor sandy lands of eastern North Carolina.

In South Carolina a very elaborate and most carefully conducted series of experiments was made upon the station farms (two), situated

in different sections of the State, and extending over three years—1888–1890. The soils selected were typical of the “upland” soils of the cotton States, and were “very thin, being greatly exhausted by years of improvident culture.” Applications of fertilizers (phosphatic, nitrogenous, and potash) of various kinds were made, separately and in various combinations, and in different amounts, but more particularly in the approximate quantities and proportions shown by existing analyses of the cotton plant to be necessary for the requirements of the crop. The details of the experiments and the results have been reported in a bulletin of the United States Department of Agriculture.<sup>1</sup> The conclusions reached are in part as follows:

- (1) Cotton requires nitrogen, phosphoric acid, and potash.
- (2) Of the three, phosphoric acid is relatively the most important and controls the action of the other two. It can be used alone with some advantage to the crop, but much more effectively in connection with potash and nitrogen.
- (3) Nitrogen is relatively more important than potash. It can only be advantageously used in combination with phosphoric acid or phosphoric acid and potash.
- (4) Potash, like nitrogen, is of little value to cotton when applied separately; it must be combined with the other constituents.
- (5) Expressed in terms of the latest analyses of the cotton plant, the proportions and amounts of nitrogen, phosphoric acid, and potash required are as follows: Between three-sevenths and four-sevenths nitrogen, about four and one-fourth phosphoric acid, and between one-third and one-half potash. With proper allowance for the cost, as well as the effect of each application, the requirements may be more exactly given as follows: Nitrogen, 0.43; phosphoric acid, 1.16; potash, 0.38. In other words, the required proportions are: Nitrogen, 1; phosphoric acid,  $2\frac{1}{4}$ ; potash,  $\frac{3}{4}$ ; and the amounts called for by a crop yielding 300 pounds of lint per acre are: Nitrogen, 20 pounds; phosphoric acid, 50 pounds; potash, 15 pounds.
- (6) The amount of phosphoric acid determines the amount of nitrogen and potash. With a given amount of the first, only certain amounts of the last two can be profitably used.
- (7) Potash can be as effectively supplied by muriate of potash or kainit as it can by sulphate of potash.
- (8) Phosphoric acid is of value to cotton in proportion to its solubility; hence, the several kinds of phosphatic manures can not be indifferently employed. Preference must be given to acid phosphates containing considerable percentages of soluble phosphoric acid. Insoluble phosphoric acid in slag, floats, or marl is of little direct value to the crop upon which it is applied, and even granting that its effects in the soil may be lasting they are not, in the long run, sufficiently pronounced to meet the interest on the capital invested in the application.

(9) Inorganic, organic, and mixed nitrogen are of very nearly equal value to cotton. The slight difference is in favor of the last two. Stable manure containing organic nitrogen is the best fertilizer of its class, and is lasting or cumulative in its effects. The organic nitrogen of stable manure, to the amount of 50 per cent, can be fully replaced by the inorganic nitrogen of nitrate of soda. As between cotton seed and cotton-seed meal, there is a slight difference in favor of the latter. Whole cotton seed is as efficacious as ground cotton seed. Inorganic nitrogen in nitrate of soda is about as valuable to cotton as organic nitrogen in cotton seed or cotton-seed meal.

The results obtained in Georgia and South Carolina are worthy of special consideration in this connection, as the experiments yielding them were conducted specifically for determination of the points now under discussion.

**THE AMOUNT OF FERTILIZER PER ACRE GIVING BEST RESULTS.**

The experiments bearing upon this question are somewhat meager and the results uncertain. The amount of fertilizer which may be judiciously and profitably employed is shown clearly to depend upon the character, condition, and previous treatment of the soil, and to some extent upon the season. Very few systematic experiments have been made to test this specific question.

In Alabama one series of experiments indicated that an application of 1,000 pounds per acre of a complete fertilizer was not as profitable as one of 500 pounds, although the yield was somewhat increased.

In Georgia large doses of fertilizer applied at planting or during the earlier periods of growth resulted in earlier maturity of the crop, without, however, sensible increase in profit. The results of experiments conducted for several years on series of plats of gravelly gray soil with yellow subsoil, in which fertilizers were applied at the rates of 400, 600, and 1,200 pounds per acre, indicated—

(1) That, while heavy doses of fertilizers do not give a corresponding increase in the yield of cotton, or so large a percentage of profit, yet such heavy applications, within reasonable limits, are judicious, provided the land is in good condition.

(2) That the limit or maximum amount of fertilizers that can be safely and profitably applied to land in good condition varies considerably, say from 500 to 1,000 pounds per acre, according to seasons, variety of cotton, etc. In these experiments the maximum amount that was immediately profitable was probably between 500 and 700 pounds per acre.

It is concluded that, in general, the most effective amount of fertilizer was 652.6 pounds per acre, compounded as follows:

	Pounds.
Acid phosphate .....	468
Nitrate of soda .....	130
Muriate of potash .....	54.6
	<b>652.6</b>

or such an equivalent amount of similar mixtures as will furnish per acre, approximately, phosphoric acid, 70 pounds; nitrogen, 20 pounds; potash, 20 pounds.

It has been shown that \$8 worth of a well-balanced fertilizer may be expected to increase the yield of seed cotton on 1 acre 1,000 pounds. But such results can only be attained by concentrating the fertilizer on the best land, not by scattering it at the rate of 100 or 200 pounds to the acre over a large, worn-out plantation. The mistake should not be made of applying large amounts of concentrated fertilizers on thin, worn-out land. The larger the application the more important is it that the land be in the best possible condition.

In North Carolina heavy applications of stable manure, while somewhat proportionately increasing the yield, were not profitable.

In South Carolina it is concluded that "the amount of phosphoric acid and proportionate amounts of nitrogen and potash can not be indefinitely increased with the expectation of obtaining a corresponding increase in the crop. The gain in crop does not keep pace with increase of fertilizers, and a point is speedily reached beyond which this gain is not sufficient to meet the additional cost of the heavier applications. The soil can not be profitably forced; the application of fertilizers must be regulated by its mechanical as well as chemical condition." The maximum quantity of fertilizer that can in general be used with advantage is concluded to be an amount that will furnish per acre phosphoric acid, 50 pounds; potash, 15 pounds; nitrogen, 20 pounds.

#### BEST MODE OF APPLICATION OF FERTILIZERS TO COTTON.

In Alabama experiments in 1887 indicated that broadcasting compost and stable manure gave better results than application in the drill.

In Georgia the results of general experiments indicate that "it is by no means necessary, nor is it desirable, to broadcast the fertilizer when less than 1,500 pounds are to be applied to an acre of corn or cotton or other wide-row crop. If only 500 pounds are to be applied, distribute it in a deep furrow and mix it by running two scooter furrows through it. If more than 500 pounds, then divide the amount between the center furrow and the two listing furrows. Broadcast manuring should, as a rule, be confined to crops that are planted broadcast, as small grain, grass, etc."

The experience and the practice at the stations generally substantiate the conclusion reached in South Carolina that "fertilizers may be indifferently drilled or broadcasted where they are liberally applied, but drilling is to be preferred where small amounts are employed."

#### BEST TIME OF APPLICATION OF FERTILIZERS TO COTTON.

A number of experiments have been made to test the effects of inter-cultural applications of fertilizers, the results of which, however, are for the most part discordant and inconclusive.

In Alabama one set of experiments, in 1888, indicated that one application of the fertilizer in the drill before planting gave best results.

[Another, in 1890, was very carefully conducted] in order to test the efficacy of the application of additional fertilizer during the growth of the plant in prolonging its fruiting period and increasing the yield. Two hundred pounds of cotton-seed meal per acre were applied at the second plowing of the cotton, June 18, and covered lightly with the scrape. Two hundred more were applied in the same way at the last plowing, July 30. These were applied to two plats to which 200 pounds of cotton-seed meal and acid phosphate, mixed in equal parts of each, were applied in the drill before planting, and were compared with a third plat to which the same quantity of cotton-seed meal and acid phosphate were applied at planting, but to which no subsequent applications were made. The average increase caused by the additional applications was 339 pounds of seed cotton per acre. The intercultural applications had the effect of continuing the growth and fruitfulness of the cotton after that on plat 3 had ceased to grow.

In 1893, however, it was found that 200 pounds of mixed nitrate of soda and cotton-seed meal applied (to previously fertilized plats) in June was as profitable as 100 pounds in June and 100 pounds in July. The addition of cotton-seed meal as late as August 13 was not profitable.

In Georgia it has been found that marked effects result from intercultural fertilization, or successive applications of fertilizers during the growing season. When a heavy application of a readily available fertilizer is to be made, it would be advisable to divide it into at least two doses, and possibly more.

In Louisiana the conclusion is reached that fertilizers for cotton should all be applied at time of planting. A second and third application is not profitable.

#### MISCELLANEOUS EXPERIMENTS.

Incidentally to the main objects for which the experiments in the fertilization of cotton were instituted, certain indications on miscellaneous and minor points have been afforded.

The general experience at the stations and elsewhere is to the effect that chemical manures generally, and especially nitrogenous and phosphatic manures, hasten the maturity of the crop. Stable manure in some instances (Arkansas, North Carolina) delayed maturity beyond the fruiting period.

The cumulative effect of manures in the soil is fairly well evidenced in several cases. Nitrogenous manures increased the yield the second season without additional fertilization (Alabama, Arkansas), but not the third season (Alabama). Phosphatic manures increased the yield, without additional fertilization, the second and third seasons (Alabama). The cumulative effects of heavy applications of a complete fertilizer were manifest the second and the third years (Georgia). Floats alone gave a greater increase over no manure the third year after application than in the first or second year (Alabama).

Kainit is recommended as a specific for rust and blight in cotton, to

be used in connection with cotton seed or cotton-seed meal (North Carolina). Kainit appears to retard the appearance of blight (Alabama). Kainit retards the opening of the bolls (Arkansas).

"Marl, alone or in combination with commercial fertilizers, is of no direct value to cotton. Applied upon leguminous crops, which are to be turned under as a preparation for cotton, its indirect value is great" (South Carolina). Air-slacked lime mixed in the drill with acid phosphate and floats had no apparent effect upon the crop (Alabama).

Applications of copperas are without effect upon cotton (South Carolina).

Nitrate of soda should generally be applied with the other fertilizers at the time of planting (South Carolina); but, on the other hand, it may be profitably divided into two applications, the second not to be later than June 1 (Georgia).

The quantity of nitrogen in the fertilizer seems not to affect the relations between the weight of seed and lint (Alabama).

Shallow applications of fertilizers (i. e., at depth of 2 or 3 inches) give better results than deeper applications (Louisiana).

There is no advantage in separating the ingredients of the fertilizer and applying them at different depths (Louisiana).

It is highly important that the fertilizer be well mixed with a considerable portion of soil (Georgia).

The cowpea is an excellent green manuring crop in preparation of land for cotton (Alabama, Arkansas, Louisiana, Georgia). The most profitable method of application is to gather the peas, or cut the vines for hay, and turn under the stubble with addition of the manure from stock fed with the hay (Alabama, Arkansas, Georgia).

#### GENERAL CONCLUSIONS.

In reviewing the results of the experiments conducted at or under the auspices of the experiment stations, and taking into account the general experience of successful cotton growers, certain general conclusions on the subject of the fertilization of cotton may be accepted as tentatively established:

(1) Cotton is a plant which responds promptly, liberally, and profitably to judicious fertilization.

(2) By judicious fertilization the maturity of the crop may be hastened and the period of growth, from germination to fruiting, so shortened as to materially increase the climatic area within which cotton may be profitably grown.

(3) As is the case with most other crops, the profit from manuring cotton with concentrated fertilizers is much enhanced by antecedent proper preparation of the soil. It pays to bring cotton lands up to a condition of good "tilth" by mechanical treatment, and especially by incorporating in them liberal quantities of organic matter. Upon lands

in such condition fertilizers of all kinds yield more profit, either from small or large applications, than upon lands not so treated.

(4) Renovating crops, and especially the cowpea, furnish an efficient and economical method of bringing cotton lands into condition to respond most liberally and profitably to the application of concentrated manures under cotton. The most profitable plan of employing the cowpea for this purpose on cotton is to gather the peas at maturity, cut the vines for hay, and turn under the stubble along with the manure resulting from feeding the hay to stock and cattle.

(5) Barnyard manure and similar bulky manures are more efficient and profitable as soil renovators than as specific fertilizers for cotton. They should be broadcast liberally and used rather as soil improvers than as immediate fertilizers. The same is probably true of cotton seed, except where the price to be had for the seed at cotton-oil mills justifies the exchange of seed for cotton-seed meal, to be used as the source of nitrogen in a concentrated manure. If, however, only small quantities of such manures are to be had, and it is desired to use them as direct fertilizers, it is more profitable to compost them with acid phosphate (preferably containing a small percentage of potash) than to use them alone. It is more profitable to compost directly in the drill at time of planting than in heaps previously.

(6) Cotton may wisely be assigned a place in a judicious rotation system. Upon lands devoted to staple crops a three years' rotation—small grain, corn (with peas), cotton—is judicious. Each crop in the rotation should be appropriately fertilized. It is in evidence that the cumulative effects of such manuring upon the succeeding crop are marked.

(7) Upon the great majority of the soils of the cotton-growing States it is advisable and profitable to use, as a concentrated fertilizer, a "complete manure," i. e., one containing soluble phosphoric acid, available potash, and available nitrogen, rather than a manure containing only one or two of these ingredients. Nitrogen, however, may probably be advantageously omitted from the concentrated fertilizer, in whole or in part, when the soil has previously been liberally supplied with this ingredient, through barnyard manure, green manuring, etc.

(8) "Soluble" phosphates are very much to be preferred in the fertilizer for cotton to those which are not soluble.

(9) There is no great difference, if any, in the agricultural value and profit, when used in the fertilizer for cotton, of the various soluble potash salts to be had in commerce, except proportionately to the price and content of actual potash.

(10) Of the nitrogen compounds available for use in fertilizers the organic forms (vegetable and animal) are perhaps best suited to cotton, if one form alone be used, although nitrate of soda is probably nearly if not quite of equal value. Further experiments are needed to determine the efficacy of mixing various nitrogen compounds in different proportions.



(11) The most judicious proportions of soluble phosphoric acid, potash, and nitrogen in a complete fertilizer for cotton can not be said to have been as yet determined with entire accuracy. Those suggested by Georgia—nitrogen 1, potash 1, phosphoric acid  $3\frac{1}{2}$ —and by South Carolina—nitrogen 1, potash  $\frac{3}{4}$ , phosphoric acid  $2\frac{1}{4}$ —perhaps approximate reasonable accuracy. In the light of present information, perhaps nitrogen 1, potash 1, phosphoric acid  $2\frac{3}{4}$  or 3 would not be injudicious proportions for general use.

(12) The amount of concentrated fertilizer which may profitably be used per acre varies widely with the nature and condition of the soil, the seasons, and other circumstances. For an average soil in fairly good condition perhaps the maximum amounts indicated by Georgia (nitrogen, 20 pounds; potash, 20 pounds; phosphoric acid, 70 pounds), or by South Carolina (nitrogen, 20 pounds; potash, 15 pounds; phosphoric acid, 50 pounds), or an approximate mean of the two would be the maximum limit of profitable application. The actual weight of the complete fertilizer furnishing these quantities would, of course, vary with the percentage composition in nitrogen, potash, and phosphoric acid of the materials used to make the fertilizer. If the commercial “ammoniated” fertilizer or other concentrated manure intended for use under cotton should be compounded (as it might very well be, and in some cases is) to analyze approximately—

	Per cent.
Soluble (available) phosphoric acid.....	9
Potash.....	3
Nitrogen.....	3

then 700 pounds per acre of such a fertilizer would be approximately the maximum amount that could judiciously and profitably be used, under ordinary circumstances, upon soil in good condition.

(13) The concentrated fertilizer should be applied in the drill (not broadcast) at a depth of not more than 3 inches, and well mixed with the soil.

(14) All things considered, it is perhaps best in most cases to apply all the concentrated fertilizer in one application at the time of planting. With lands in superior condition, however, or where large quantities of fertilizers are used, it is probably profitable to apply half at planting and half at the second plowing.